Experience with AC Extended Optimal Power Flow (AC XOPF)

Marija Ilic, milic@netssinc.com

Jeffrey Lang , jeffrey.lang@netssinc.com

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Premise

The purpose of an electric power system is to deliver real power to the greatest number of users, at the lowest possible cost and with the least possible pollution, all the time

Today's Practice

- … is focused on ``all the time''.

- … follows a preventive approach to resource management that is generally more costly and dirtier than need be, and generally serves fewer users given fixed assets.

- … could be replaced by a corrective approach to serve a greater number of users at a lower cost and with less pollution without adding more assets.

Enabling Corrective Resource Management

- Must adjust resources as conditions change to guarantee ``all the time''.

  - Must operate resources within their thermal and voltage limits.

  - Must manage power transfer limits within the system.

- The best performance is obtained by adjusting the most resources.

The Role of Extended AC OPF (AC XOPF)

- Must be AC in order to manage voltage limits and balance reactive power.

- Optimal corrective resource management is highly combinatorial.

    - Iterative analysis is inadequate.

    - Optimal decision making (XOPF) is required.

- Optimization criteria must be responsive to changing system conditions (XOPF).

Importance of voltage optimization

- Many resources (generators, FACTS, transformers, shunts) can control voltage requiring AC XOPF for their optimization

- Without voltage optimization some assets can not be utilized up to their thermal limits

- Voltage optimization enables serving a greater number of users at a lower cost and with less pollution without adding more assets, all the time.

Economic Dispatch Illustration

- FERC 715 case, summer 2014, peak load; truncated south and west of PJM and IESO

- Fuel costs used as generation bids

- Studied base case and six critical contingencies. Qualitatively similar results observed for all seven optimizations demonstrating the ability to operate well all the time.

- Minimum generation cost optimization.

Control Combinations
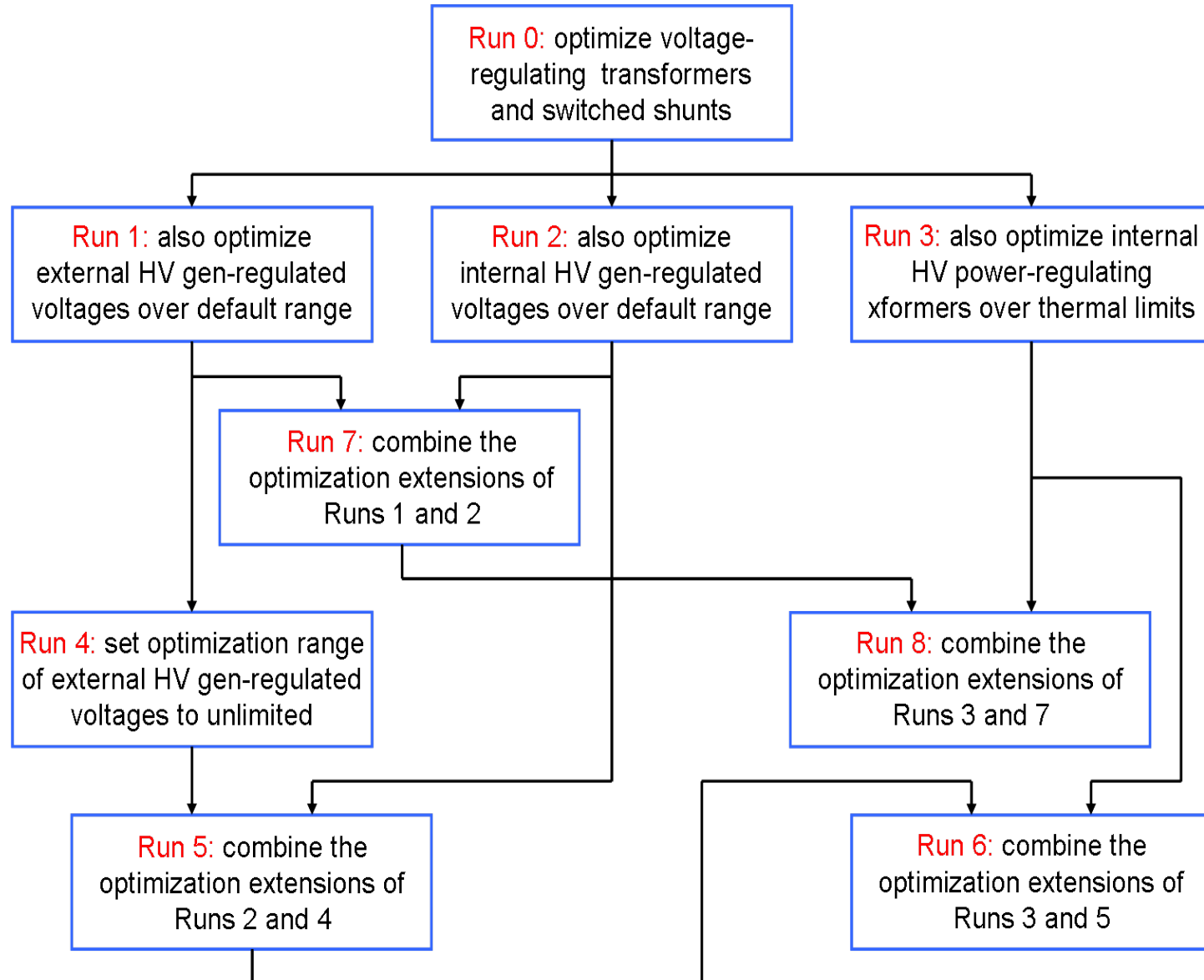
Base case results

Case	Generation Cost [$/Hr]	Annual Savings
A No voltage control	1205958	Benchmark
B NYCA x-former dispatch	1133203	$637M
00	1115321	$794M
01	1110705	$834M
02	1115025	$796M
03	1098848	$941M
04	1068956	
05	1063000	
06	1018623	
07	1110290	$838M
08	1094488	$980M

Zonal Economics (Run 0)

Zone	Load Power [MW]	Gen Power [MW]	Gen Cost [$]	Load Charge (LMP) [$]	Gen Revenue (LMP) [$]	Gen Profit (LMP) [$]	Merchnds Surplus (LMP) [$]	Load Charge (Stack) [$]	Gen Revenue (Stack) [$]	Gen Profit (Stack) [$]	Merchnds Surplus (Stack) [$]
A	2630	4909	81654	168585	265064	183410	-96479	249844	466390	384736	-216546
B	1904	804	10931	116446	47868	36937	68578	180845	76399	65468	104446
C	2818	5021	108263	208975	347679	239416	-138705	267689	477014	368751	-209325
D	800	1225	12685	57319	85818	73133	-28499	76000	116385	103700	-40385
E	1200	858	6825	94090	59470	52645	34620	114000	81522	74697	32478
F	2234	3334	112715	185775	271524	158809	-85748	212230	316716	204001	-104486
G	2311	1874	90787	207849	166437	75650	41412	219542	177988	87201	41554
H	705	2187	17054	64858	195602	178548	-130745	67022	207734	190679	-140712
I	1406	0	0	129351	0	0	129351	133566	0	0	133566
J	11417	6316	462966	1088142	551544	88577	536598	1084628	600000	137033	484628
K	5460	4601	211440	469953	370108	158669	99844	518700	437116	225676	81584
NY	32885	31129	1115321	2791342	2361115	1245794	430227	3124066	2957263	1841943	166802

Load Charge Differences
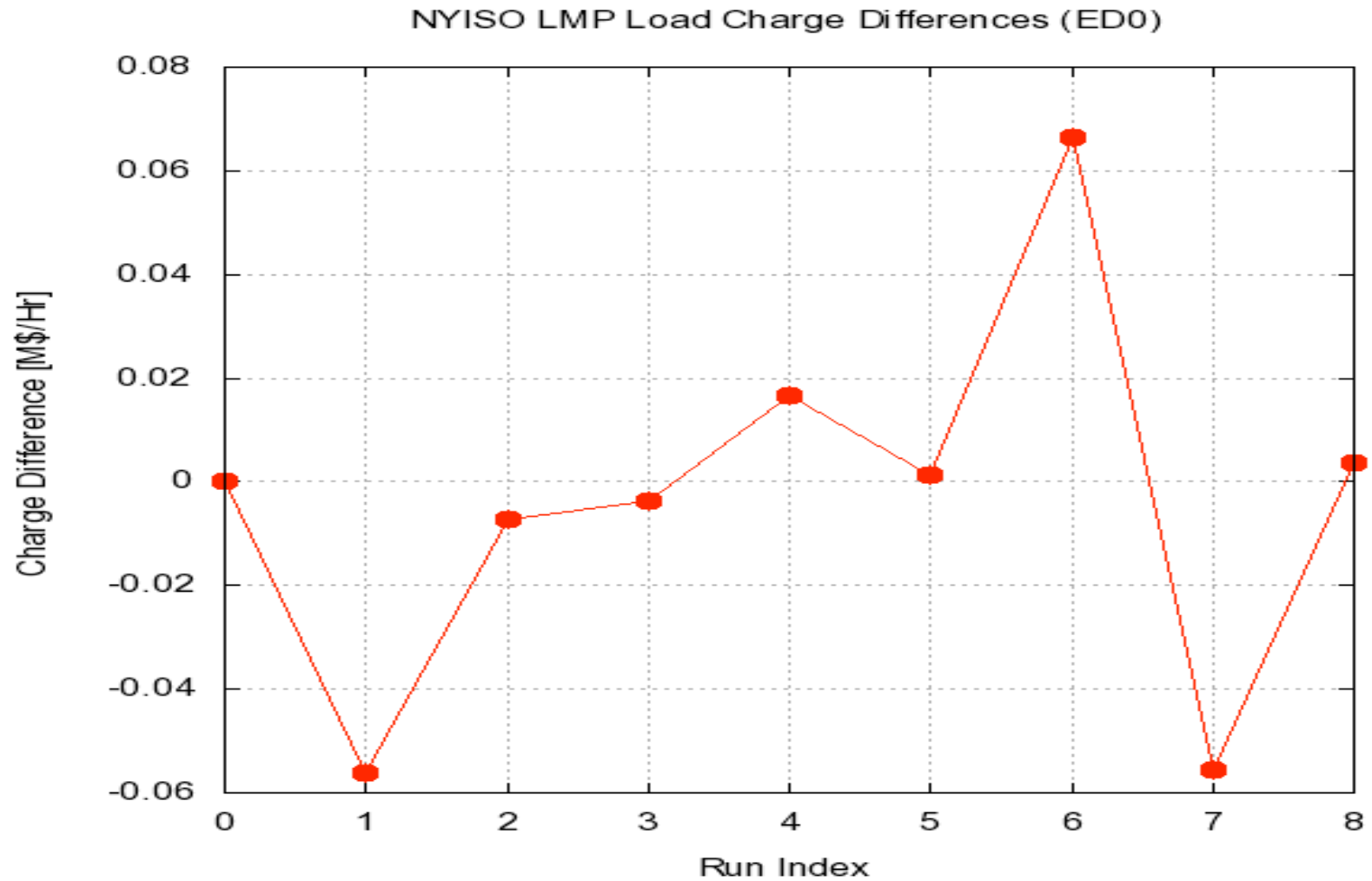
Generation Profit Differences

NYISO LMP Generator Profit Differences (ED0)

Merchandise Surplus Differences

NYISO LMP Merchandise Surplus Differences (ED0)
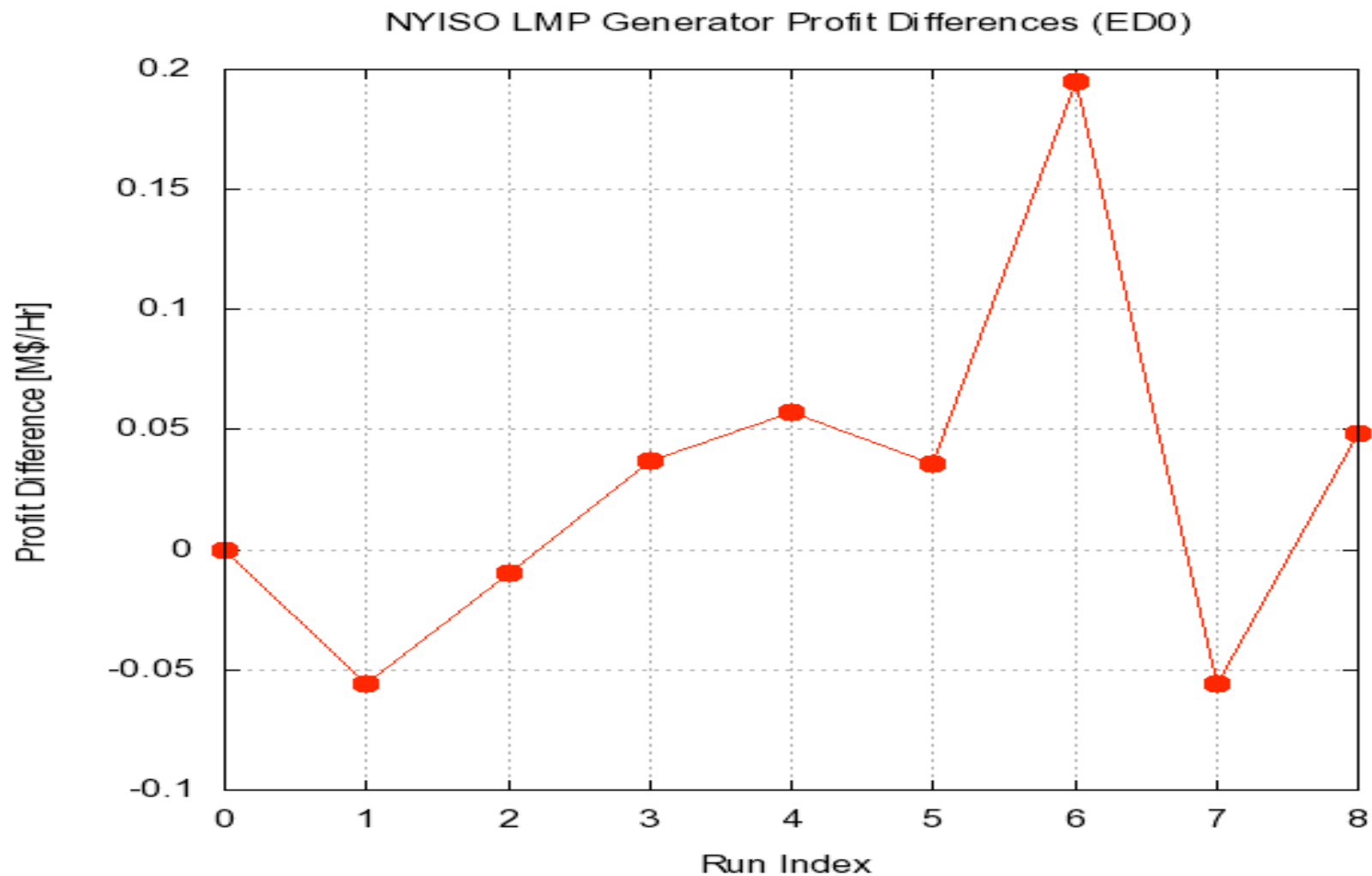
Comparison of Bus Voltages (Run 2)
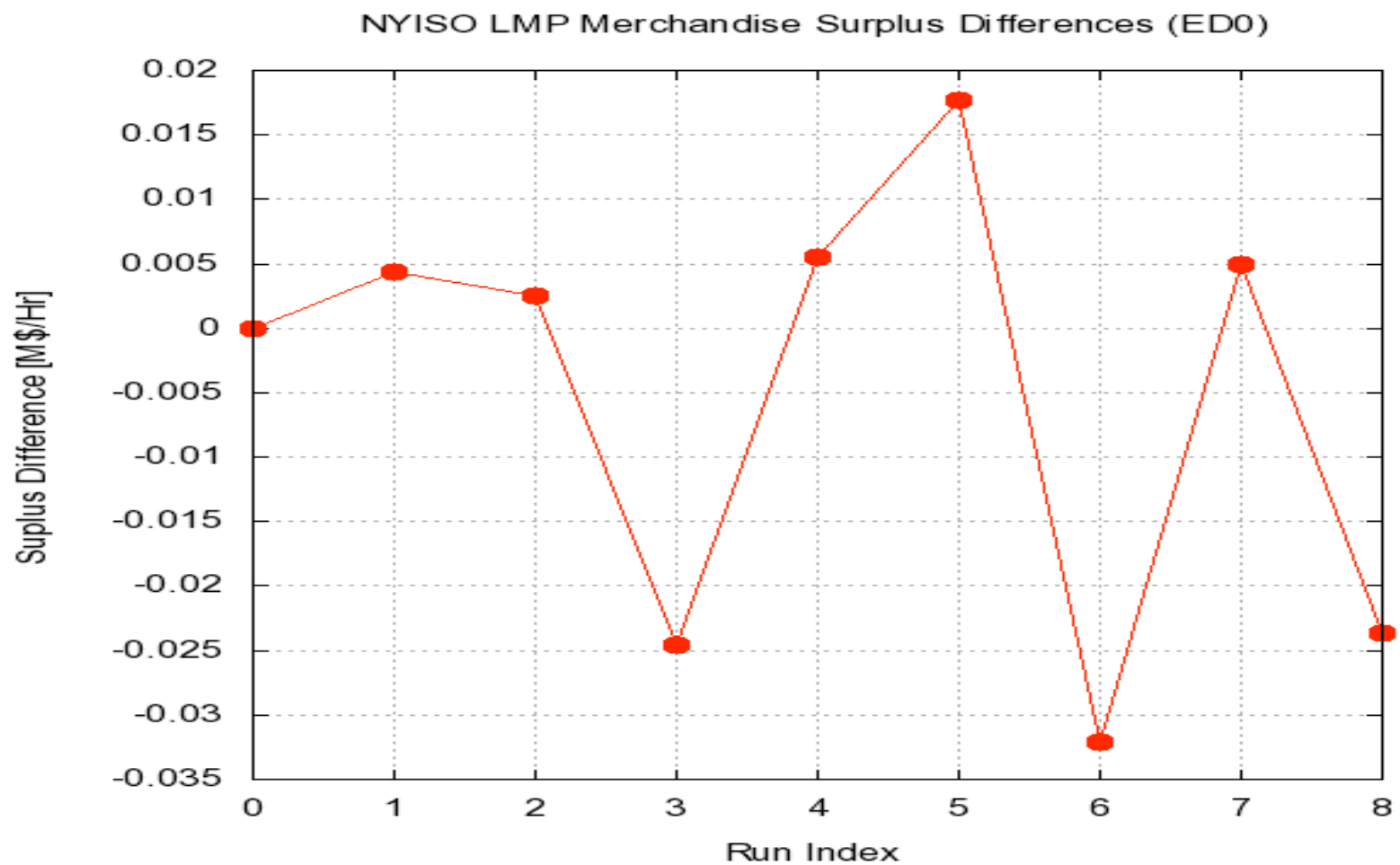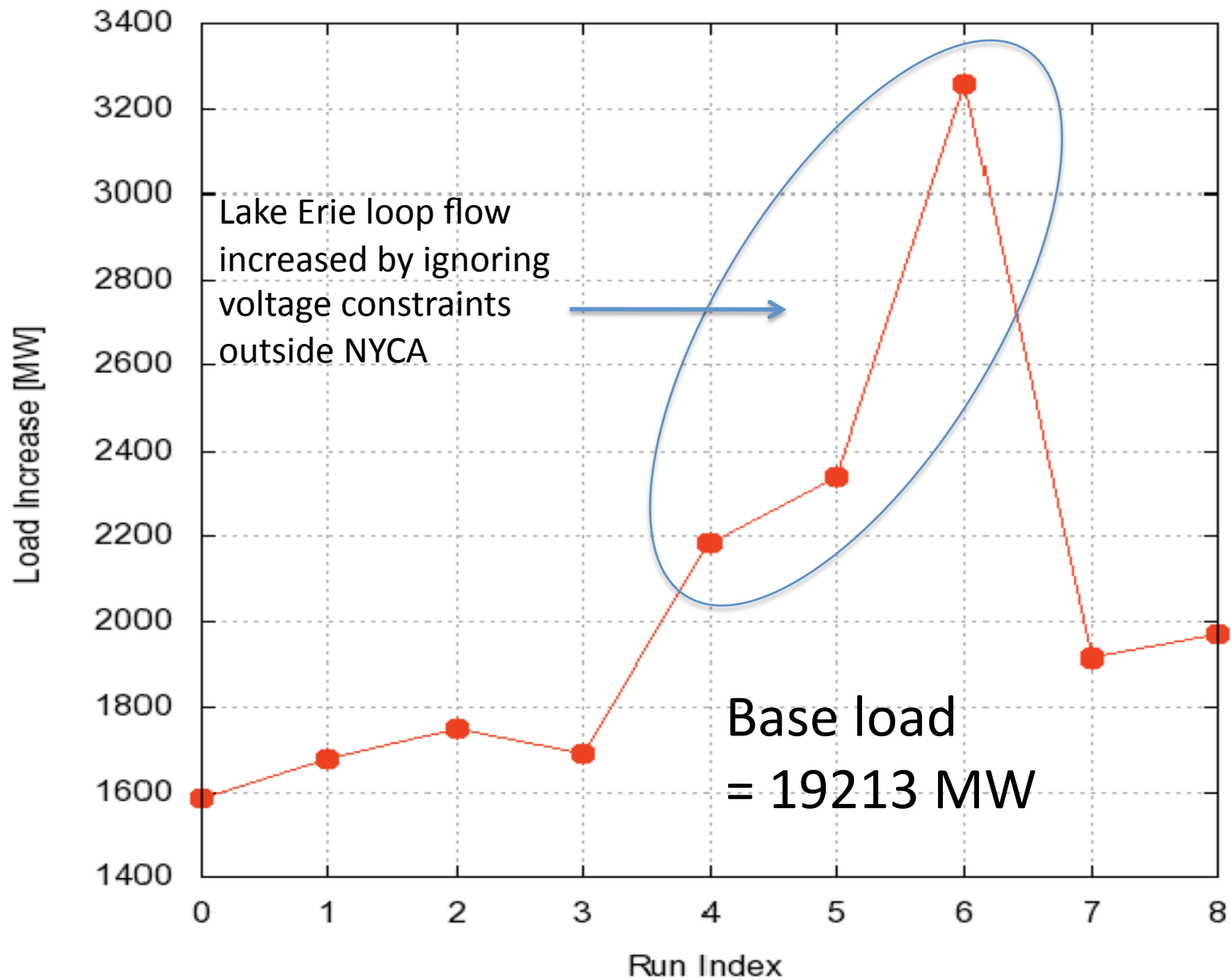

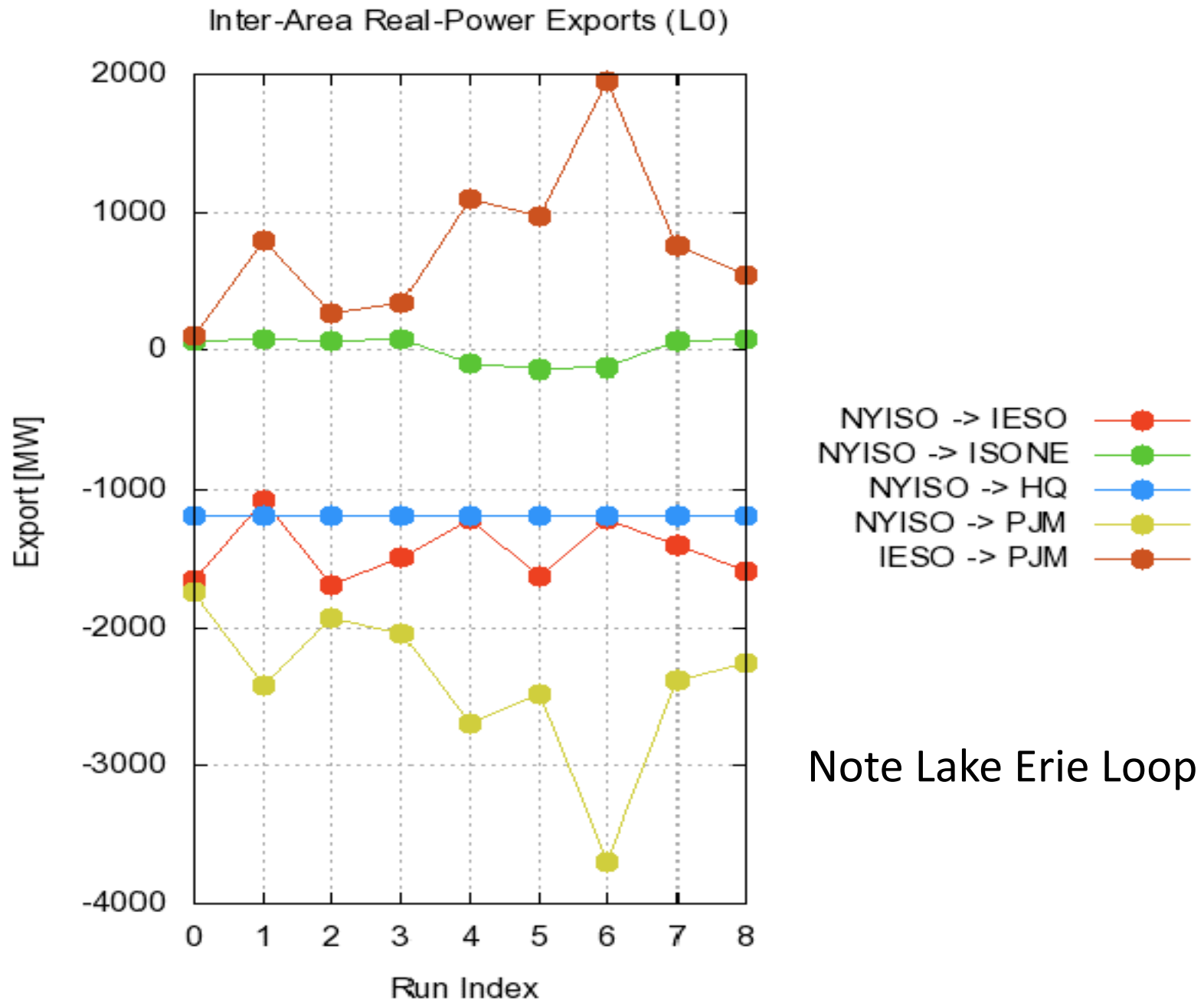NYISO High Voltages (ED0 RUN=2)
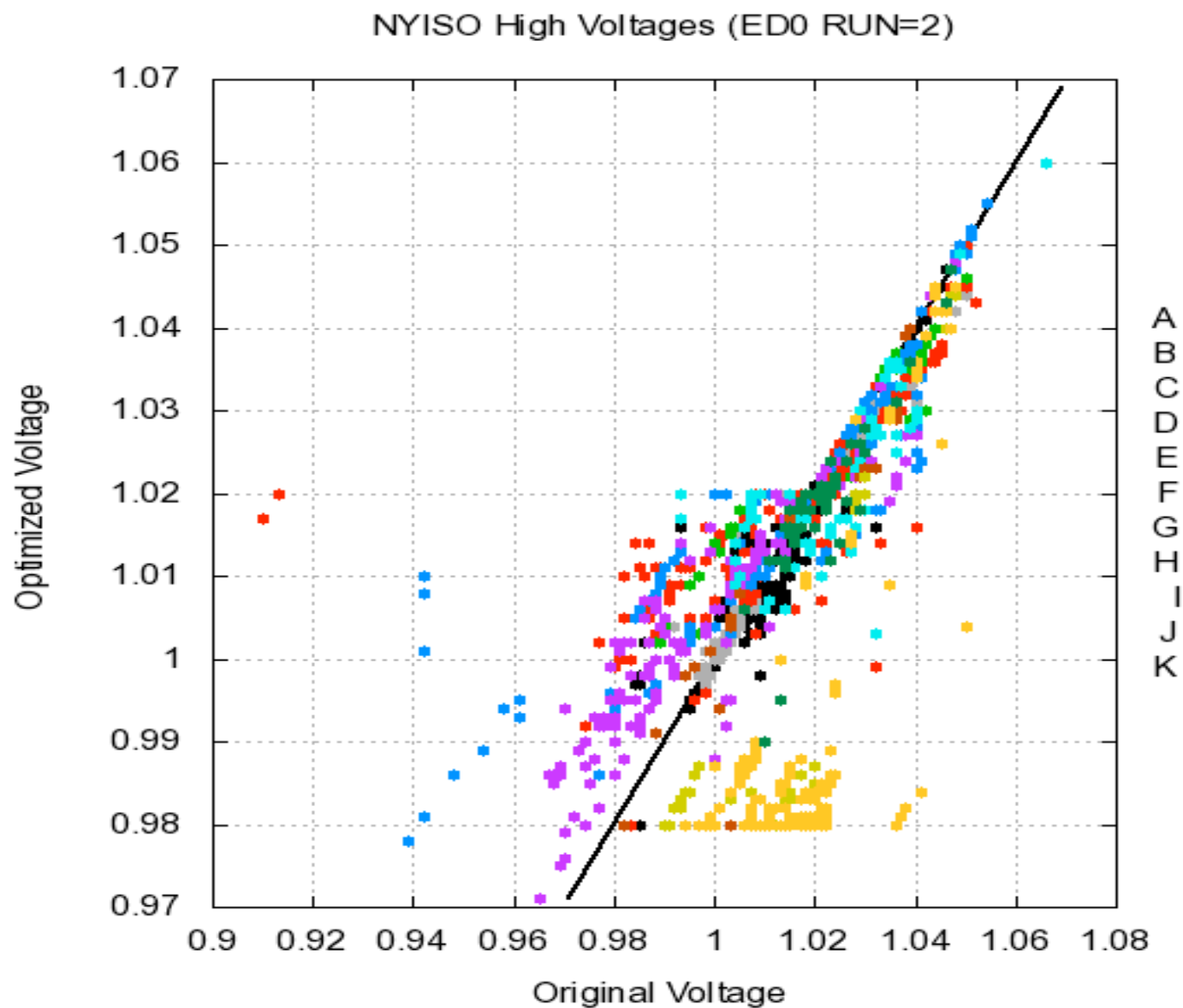
Loadability Illustration

- FERC 715 case, summer 2014, peak load; truncated south and west of PJM and IESO

- Studied base case and six critical contingencies. Qualitatively similar results observed for all seven optimizations.

- Maximize the load served in NYC using extra generation in Canada.
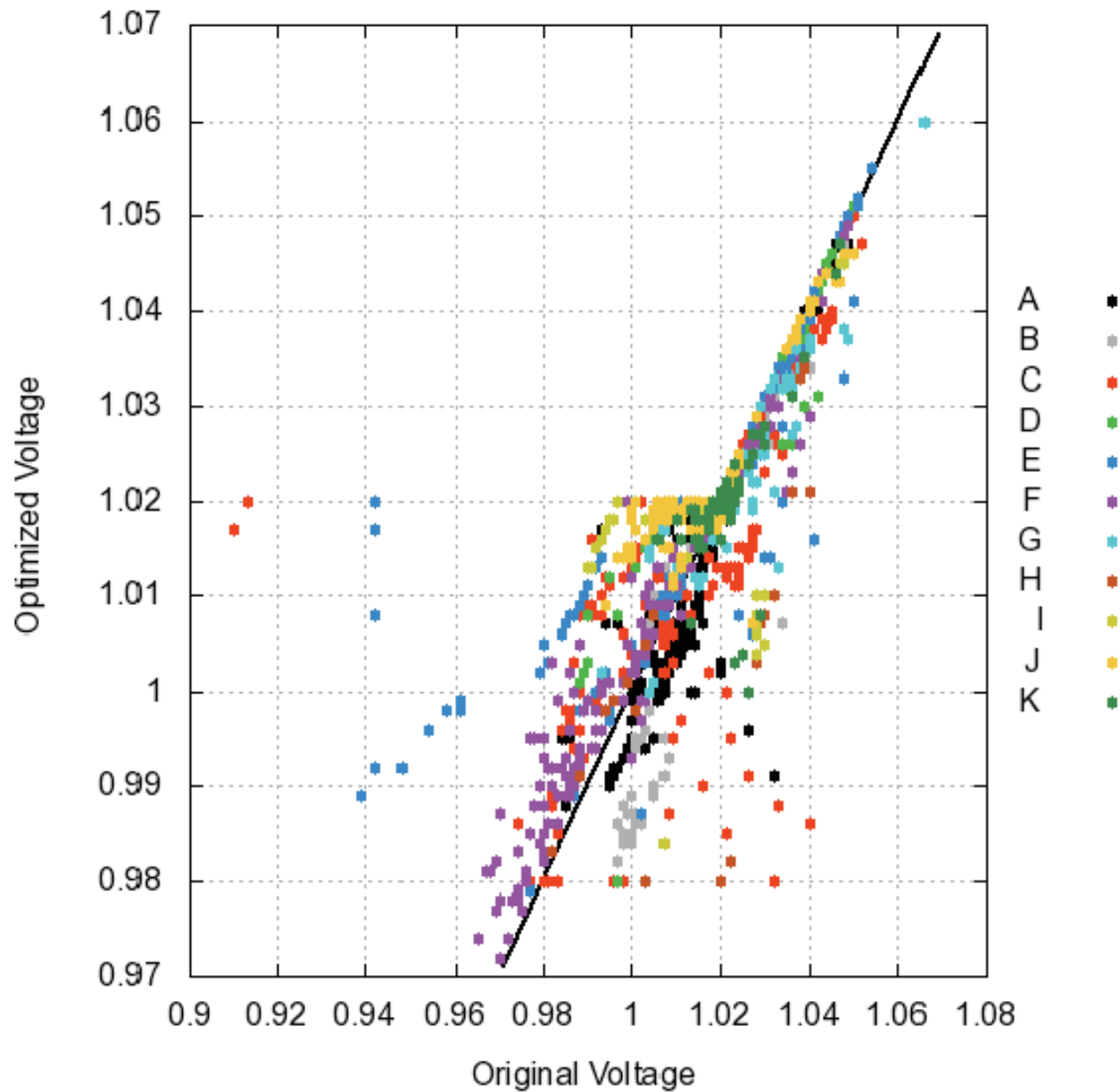
Load Increase in NYC

Load Increase In Areas 9-11 (L0)

Lake Erie loop flow increased by ignoring voltage constraints outside NYCA

Base load = 19213 MW

Inter-area Real Power Exports

Inter-Area Real-Power Exports (L0)

Note Lake Erie Loop

Comparison of Bus Voltages

NYISO High Voltages (L0 RUN=2)

Conclusions

- Voltage optimization is very beneficial to minimizing cost and serving greater loads all the time.

- Voltage constraints sometimes hide thermal constraints until voltage is optimized

- Transformers present the most serious thermal limits in NYCA

- Multiple optimization are useful in managing resources